Condensed matter student symposium

Fall semester, Jan 14, 2019, Melamed hall

Schedule:

9.10-10.00 **Alon Cohen** (PhD, Moshe Schwartz)**:**
Applications of the Self-Consistent Expansion

10.00-10.25 **Noa Feldman** (MSc, Moshe Goldstein)**:**
Charge Resolved Entanglement Entropy and Negativity after a Local Quantum Quench

10.25-10.50 **Hadas Shem-Tov** (MSc, Yair Shokef):
Degeneracy partially restored in sheared colloidal square ice

10.50-11.10 Coffee break

11.10-12.00 **Michael Mograbi** (PhD, Yoram Dagan):
Vortex excitations in the Insulating State of an Oxide Interface

12.00-12.50 **Ram Adar** (PhD, David Andelman):
Theory of ionic solutions: complex bulk and surface structures

12.50 -13.35 Lunch (Shenkar lobby)

13.35 -14.00 **Ben Slavin** (MSc, Alon Bahabad):
Evolution of guided modes under spatiotemporal perturbation

14.00 -14.50 **Guy Jacoby** (PhD, Roy Beck):
A long-lived metastability in lipid particles

14.50- 15.10 Coffee Break

15.10 -16.00 <u>Guest lecture</u>: **Prof.Dr. Gijsje Koenderink (AMOLF)**
The role of cytoskeletal crosstalk in cell form and function

16.00 - Beer in the Scientists room (Shenkar third floor)

List of titles and abstracts:

Guest Lecture:
Prof.Dr. Gijsje Koenderink
Affiliation: AMOLF (Netherlands)

The role of cytoskeletal crosstalk in cell form and function

Cell shape and mechanics are determined by the interplay of four distinct cytoskeletal networks, made of actin filaments, microtubules, intermediate filaments and septins. These four types of cytoskeletal polymers differ in their structural and physical properties, enabling specific cellular functions. However, there is growing evidence that the four cytoskeletal subsystems also exhibit strongly coupled functions necessary for cell polarization, cell migration, and mechano-responsiveness. In this talk, I will discuss our own recent work addressing the biophysical mechanisms of cytoskeletal crosstalk using in vitro reconstitution of purified cellular components. I will discuss the role of crosstalk in cytoskeletal self-organization and in cell mechanics.

Alon Cohen (PhD, Moshe Swartz)

Applications of the Self-Consistent Expansion

Most of the interesting systems in statistical physics can be described as nonlinear stochastic field theories. A common feature in the theoretical study of such systems is that ordinary perturbation theory seldom works. On the other hand, there exists a useful tool for the study of systems of that generic nature. This tool, the Self Consistent Expansion (SCE), is technically similar to ordinary perturbation expansion, in the sense that it is an expansion around a solvable system. The key point which distinguishes the SCE from an ordinary perturbation expansion is that the small parameter of the expansion is adjustable and determined inherently by optimization. Therefore, it allows the adaptive SCE to mimic the actual complex system and remain accurate relative to the inflexible ordinary expansion. In this presentation, I explain the method by applying it in detail to a single degree of freedom example. Next, I will show the equations and results for the noise driven Navier-Stokes equation in d-dimensions.

Noa Feldman (MSc, Moshe Goldstein)

Charge Resolved Entanglement Entropy and Negativity after a Local Quantum Quench

Quantum entanglement and its main quantitative measures, the entanglement entropy and entanglement negativity, are playing a central role in many body systems. An interesting twist arises when the system considered has symmetries leading to conserved quantities: A recent study by Moshe Goldstein and Eran Sela introduced a way to define, represent in field theory, calculate for 1+1D conformal systems, and measure, the contribution of individual charge sectors to the entanglement measures between different parts of a system in its ground state. In my work, I apply these methods for studying the time evolution of the charge-resolved contributions to the entanglement entropy and negativity after a local quantum quench. I calculate them both numerically, using TEBD simulations on various 1D lattice models, as well as analytically for 1+1D conformal field theory description, and find good agreement.

Hadas Shem-Tov (MSc, Yair Shokef)

Degeneracy partially restored in sheared colloidal square ice

The crystal form of 3D water ice has a highly degenerate ground state, that grows exponentially with the system size. This growth of degeneracy is caused by the number of configurations conforming to the so called "two-in, two-out" ice rule, where all configurations conforming to that rule are symmetric. A simplified model which approximately obeys the ice rule and is easier to investigate experimentally at the single-particle level is given by 2D artificial square ice. In this model, symmetry is broken and the ground-state entropy vanishes.

We suggest a new model of sheared square ice. Its uniqueness is in partially restoring the degeneracy. When shearing the lattice, the second energy level split. Thus, a new energy gap between the two lowest levels emerges. We analytically calculated the energy levels and identified that this new gap between the two lowest energy states becomes relatively small as the shear angle increases. Following that we performed Monte Carlo simulations and observed that at temperatures corresponding to thermal energies larger than this energy gap, this gap becomes negligible, and occupations of the two almost degenerate states are comparable, leading to a new phase with sub-extensive entropy. We obtained our results specifically for interactions characteristic of colloids. Nevertheless, the sheared lattice model can be implemented in different systems with a separation of energy scales, e.g., colloids in optical traps, lithographically fabricated ferromagnetic islands.

Michael Mograbi (PhD, Yoram Dagan)

Vortex excitations in the Insulating State of an Oxide Interface

In two-dimensional (2D) superconductors an insulating state can be induced either by applying a magnetic field, H, or by increasing disorder. Many scenarios have been put forth to explain the superconductor to insulator transition (SIT): dominating fermionic physics after the breaking of Cooper pairs, loss of phase coherence between superconducting islands and localization of Cooper pairs with concomitant condensation of vortex-type excitations. The difficulty in characterizing the insulating state and its origin stems from the lack of a continuous mapping of the superconducting to insulating phase diagram in a single sample. Here we use the 2D electron liquid formed at the interface between (111) $SrTiO_3$ and $LaAlO_3$ to study the SIT as a function of electrostatic gate and magnetic field. This crystalline interface surprisingly exhibits very strong features observed previously only in amorphous systems. These features persist deep into the insulating state. We identify a new magnetic field scale, $H_{pairing}$, where superconducting fluctuations are muted and find a lengthscale ξ_{Ins} interpreted as the size of the vortex fluctuation in the insulating state. Our findings suggest that vortex fluctuation excitations and Cooper pair localization are responsible for the observed SIT and that these excitations surprisingly persist deep into the insulating state.

Ram Adar (PhD, David Andelman)

Theory of ionic solutions: complex bulk and surface structures

Ionic solutions are complex systems because of their large number of particles and the long-range electrostatic interactions between these particles. Consequently, standard theories of

electrolytes rely on different approximations, e.g., all the immersed objects are charged homogeneously; all ions are separate and independent entities, etc.
Although such a simplistic description is sufficient to predict physical properties of different systems, it lacks the necessary details to describe many others. Namely, a wide variety of complex structures arises in the ionic solution (bulk) or on its bounding surfaces. My dissertation deals exactly with these structures and describes their unique physical features. We describe how overall neutral surfaces with positive and negative charge patches exhibit a long-range attraction in solution, In addition, we show how the finite ion size and possible ionic pairs affect the dielectric constant of electrolytes. We relate our results to several recent experiments.

Ben Slavin (MSc, Alon Bahabad)

Evolution of guided modes under spatiotemporal perturbation

Propagation of electromagnetic waves in spatially-complex media, such as dielectric waveguides, optical fibers, periodic media and photonic crystals, has been vastly investigated in recent decades. The research of such structures contributed enormously to our knowledge and understanding of the behavior of wave propagation and, alongside with the technological advances in miniaturization capabilities, enables us to develop optical devices with sub-wavelength features which can be integrated with electronic circuits or be used as building blocks in photonic circuits. On the other hand, our knowledge on propagation of electromagnetic waves in media which posses temporally varying properties is less developed. Such media can potentially enable real-time dynamic control in optical structures as well as unique features such as temporal symmetry-breaking which can be used to realize non-reciprocal photonic devices. An example of temporally varying media can be found in nonlinear processes where the material nonlinear-susceptibility is affected by an impinging wave and vice-versa. Coupled-Mode Theory provides a theoretical framework for an efficient design of such devices. It’s main advantage is its ability to reduce the description of complex photonic structures to a simple set of equations, describing the interactions (energy exchange) between modes in the system. The process in which energy is exchanged between modes is called mode-coupling. In order to couple modes, it is often common to add a spatial perturbation to the system so that a momentum mismatch between the modes is overcome. There are many different formalisms of coupled-mode theory in optics, most of them are related to spatial perturbations. However, recently coupled-mode theory in which both spatial and temporal perturbations are involved has been developed. Together with new advances in design and synthesis of polymer-based materials with large nonlinearities and ultrafast responses, new hybrid electronic-optical applications are called upon.

In this talk, I will present a general formalism for an optical guided mode in waveguides with periodically spatial and temporal perturbed boundaries. A given mode propagating within such a waveguide is scattered in the general case into space-time harmonics. It is shown that the dynamic aspect of the modulation allows to control the spectral response of the system as well as the line-shape of resonances. Such a system offers interesting new possibilities for future electronic-optical hybrid devices where the temporal modulation is activated electronically. We validate our theoretical model using finite difference time domain simulations and demonstrate numerically a potentially applicable electronically controlled optical modulator.

Guy Jacoby (PhD, Roy Beck)

A long-lived metastability in lipid particles

Phospholipids are a main component of all cell membranes. They can form various lamellar and non-lamellar mesophases via the self-assembly process; a spontaneous organization of the molecules, attributed to their amphiphilic structure. A phase-transition can be brought about by changing thermodynamic parameters such as pressure or temperature, or by changing the lipid components in the system.

The phospholipid DLPE (dilauroyl-phosphatidylethanolamine) is known to have a highly ordered crystalline structure at temperatures below 43°C, and a disordered liquid-crystalline lamellar phase above it. When cooling a high temperature sample below this transition temperature the disordered state remains metastable for many hours, orders of magnitude longer than the transition times observed upon melting.

I study the phase-transition dynamics of this long-lived metastable-to-stable transition in solution using various techniques, such as solution X-ray scattering (SXS), cryogenic transmission electron microscopy (cryo-TEM) and differential scanning calorimetry (DSC). I will present the results of my experimental investigation into the dynamics, show that the lifetime displays a deterministic behavior (counter to the stochastic nature of classical nucleation) and can be controlled by changing various system parameters. In addition, I will briefly present a model that can account for the extended time-scales.